APPLIED X-RAY OPTICS

AXO DRESDEN GmbH **Applied X-ray Optics** Röntgenoptik und Präzisionsbeschichtung

Tailored multilayer optics for new X-ray source types

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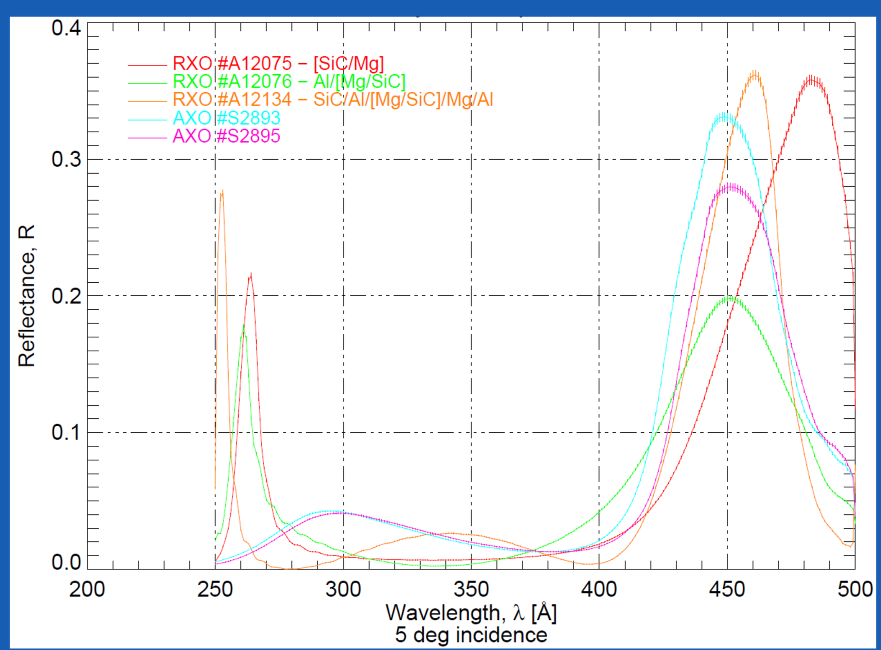
EUV Litho, Inc.

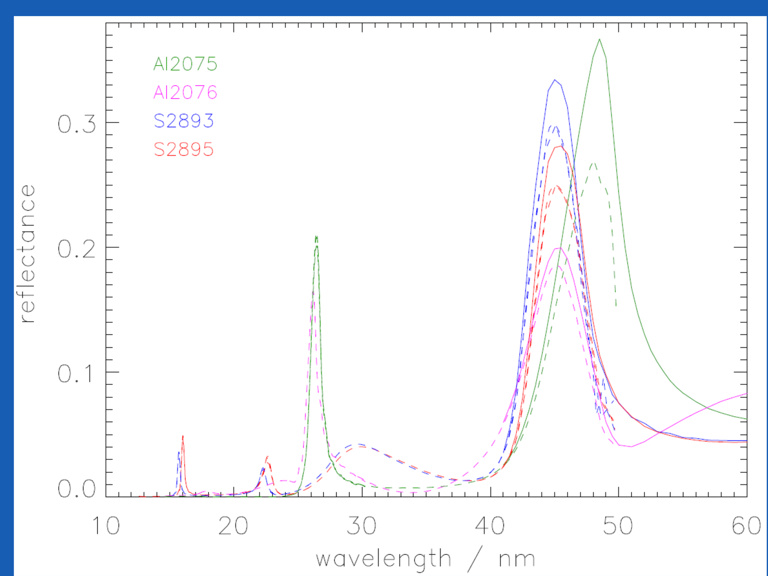
Multilayer materials for low energies

It is challenging to manufacture efficient multilayer mirrors for the UV / soft X-ray range due to the low performance of common multilayer materials in that region. A number of elements show promising optical constants in that energy range but fabrication of smooth interfaces with thermal and temporal stability is not an easy task. We have manufactured and measured Mg/SiC and Sc/Si multilayer systems that show good performance in the range between 40 and 50 nm (31 eV - 25 eV) combined with oxidation resistance by an Al cover layer.



Courtesy of E. Gullikson, ALS/LBNL, Berkeley, USA

A12075: 27.2 nm Mg/SiC
A12076: 26.6 nm Mg/SiC with Al cover layer
A12134: Mg/SiC with Al bottom & cover layer
S2893: 24.20 nm Sc/Si
S2895: 24.67 nm Sc/Si



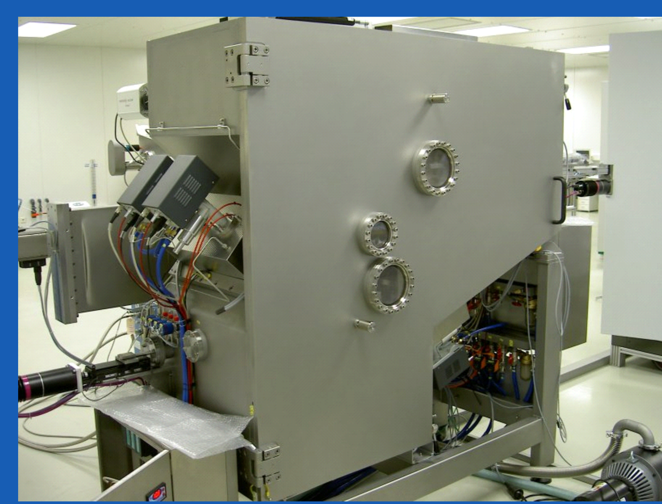
Courtesy of C. Laubis/F. Scholze, PTB, Berlin

Reflectance vs. photon wavelength of five different multilayer systems measured near normal incidence at ALS/LBNL, Berkeley, USA and PTB/BESSY, Berlin, Germany. It can be seen that the Al protection layer reduces the peak intensity somewhat (compared to a „fresh" multilayer without Al). However, careful tuning of the multilayer and cover parameters leads to a good trade-off between reflectance and stability. Sc/Si appears to be an interesting alternative with similar performance (slightly larger peak width and lower peak height).

High precision deposition of nanometer multilayers

Combination of complementary high precision deposition techniques:

- Magnetron Sputter Deposition (MSD)
  E_{part} = 10 eV: reduced intermixing
  ⇒ sufficiently smooth layers, sputter gas inclusion
- Dual Ion Beam Sputter Deposition (DIBD)
  E_{part} = 10 - 30 eV sputt. / 100 eV scattering: moderate intermixing (tunable)
  ⇒ smooth and pure layers, low droplet intensity
- Large-Area PLD (LA-PLD)
  E_{part} = 100 - 300 eV: ballistic intermixing of the individual materials
  ⇒ extremely smooth amorphous films, pure layers



Photos of the ion beam (left) and magnetron (right) deposition machines

Beam optics for laser plasma X-ray sources

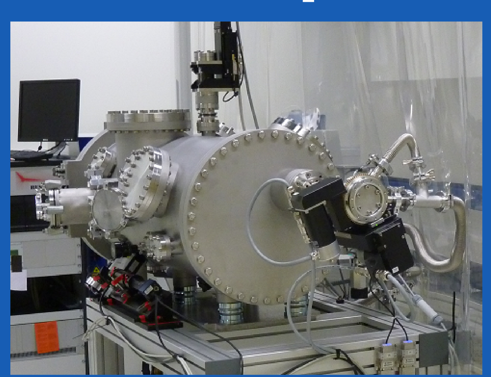
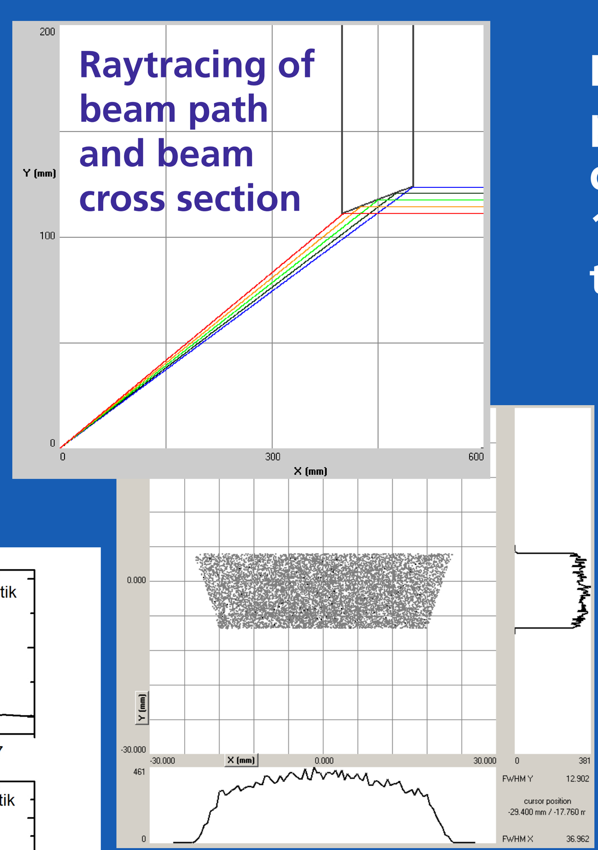
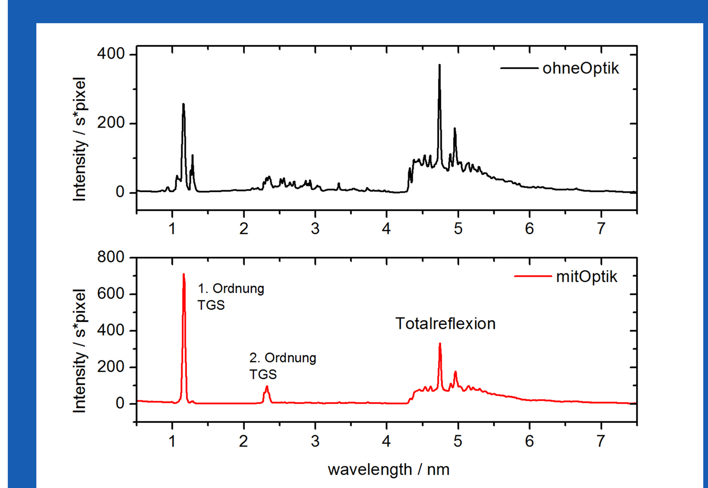


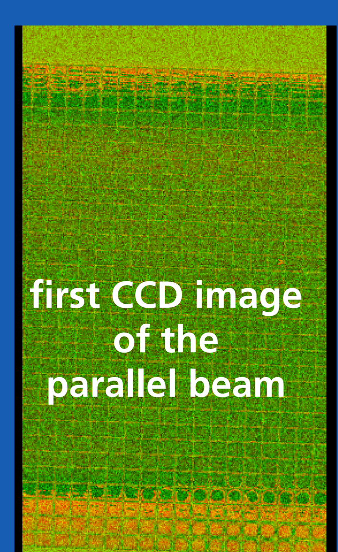
Photo of the plasma source chamber



Radiation from a laser plasma source is monochromatized (around 1000 eV) and collimated to a parallel beam.



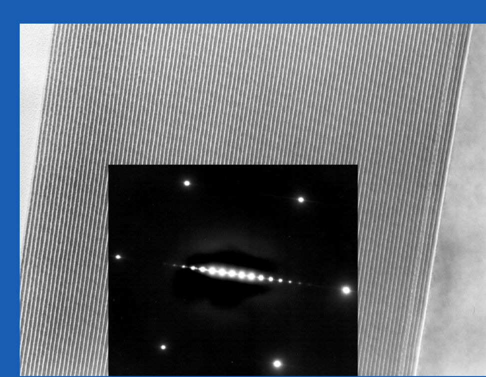
Beam spectrum before and after reflection

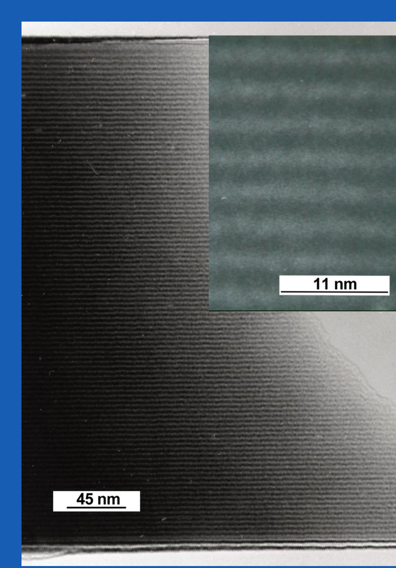


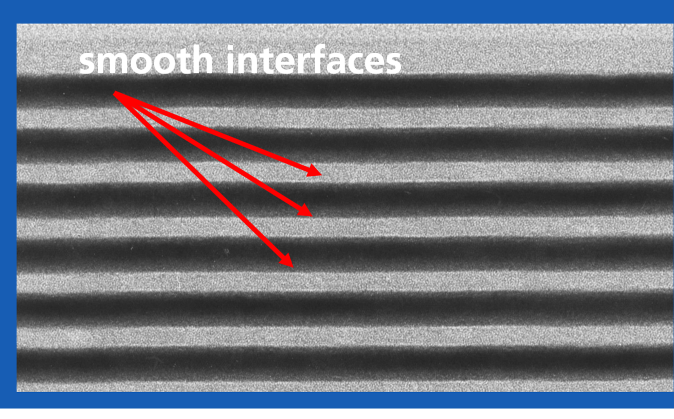
Photos and spectra courtesy of I. Mantouvalou BLiX / TU Berlin

Multilayers deposition examples

Depending on the application and requirements different multilayer materials can be deposited using various coating techniques.
These TEM images show the extremely smooth interfaces and high reproducibility of single layer thicknesses in the stack.







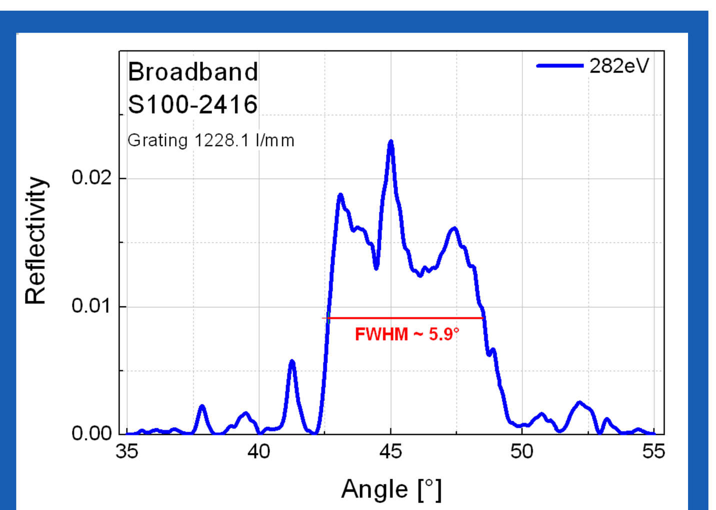
Exemplary materials:
MSD: W/Si, Pd/B_4C, Mo/Si
DIBD: Ni/B_4C, C/C, a-C
PLD: Ni/C, C/C, a-C

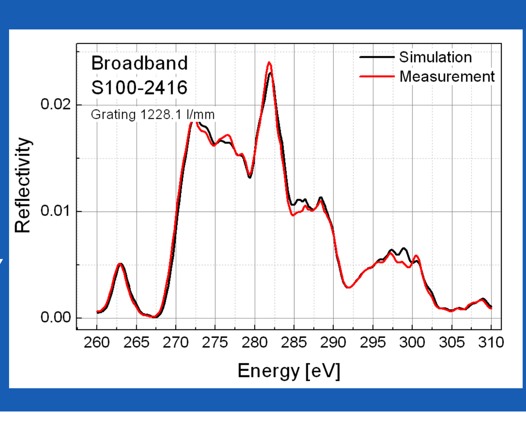
TEM images courtesy of Fraunhofer IWS

Fraunhofer IWS

Broadband polarizor

A broadband multilayer reflector for the energy region around the carbon K absorption edge (284 eV) was developed. An incidence angle around 45° delivers s-polarized radiation. The angular bandwidth of ~5.9° corresponds to an energy bandwidth of ΔE/E ~ 10%.



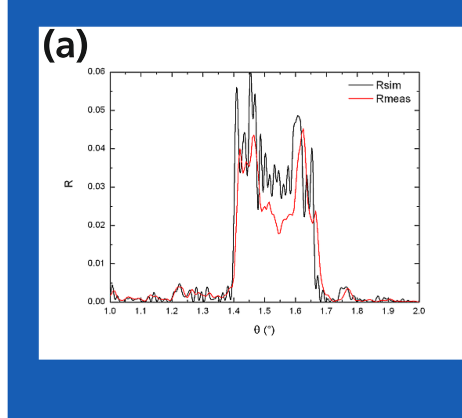


Measurements courtesy of F. Schäfers, HZB, Berlin.

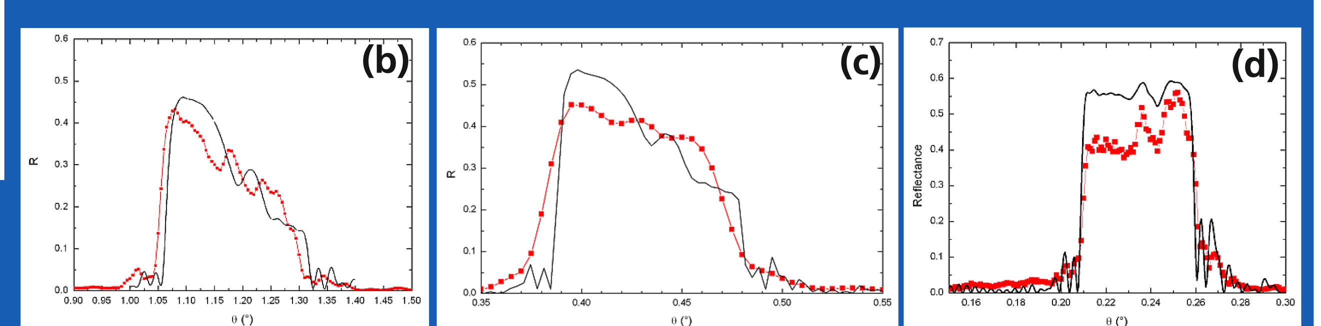
Above: Reflectance vs. incidence angle of the broadband mirror just below the C absorption edge.
Left: Reflected signal of the mirror with some C contamination. The absorption edge is clearly visible.

Broadband reflectors

By fabrication of depth-graded instead of periodic multilayers the bandwidth of a multilayer mirror can be adjusted according to customers' demands. Broadband mirrors are the most prominent example of depth-graded multilayers providing a larger integral photon flux over a selected energy range. Several broadband mirrors for soft and hard X-rays have been simulated, fabricated and tested.



a: Calculated and measured reflectivity profile for a broadband multilayer reflector optimized for a laser plasma source with E ~ 300 eV and an energy bandwidth of 17%.



Measurements courtesy of K. Mann, Laser Lab. Göttingen (a) and H.-P. Liermann and D. Novikov, HASYLAB at DESY, Hamburg (d)

b-d: Calculated and measured reflectivity profiles of a broadband multilayer mirror for hard X-rays measured in the lab with Cu Kα (8.04 keV, b) and Ag Kα radiation (22.2 keV, c) as well as synchrotron radiation (40 keV) at HASYLAB synchrotron, Hamburg (d). The energy bandwidth is around 20-22% with a peak reflectivity around 40-60%.

EUV Litho, Dublin, Ireland
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Reflective X-ray Optics

DESY

HZB Helmholtz Zentrum Berlin

BLiX Berlin Laboratory for innovative X-ray Technologies

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